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The Research on the Relationship between Industrial Development and Environmental Pollutant Emission

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Abstract

39 industry sectors in Shandong province were divided into three societies. In Society II an industrial chain linked with industries most closely was identified. Economical scale and pollutant emission of the industrial chain both had an important position in Shandong province. Ridge regression method was applied for respectively constructing models of industrial waste water, solid waste emissions and 6 manufacturing industries in the chain. The relative largest contribution to industrial waste water and solid waste emissions come from respectively clothing & leather & down product industry, food manufacturing and tobacco processing industry. This is due to common effect from pollutant transfer from upstream industries and industrial pollutant emission of its own.

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Keywords: complex network; industrial chain; ridge regression model; Shandong province

1. Introduction

1.1. The relationship between regional environmental quality and economic growth

Since Grossman (1993) found that three kinds of environmental quality indicators of sulfur dioxide, dust, aerosols and income indicator has an inverted U-relationship respectively, Arrow (1995) put forward the hypothesis that there was an inverted U-shaped relationship between the environment and economic growth [1-2]. Henceforth, the study on the relationship of regional economic growth and environmental quality has become one important academic topics that scholars are exploring.

In addition to per capita GDP[3-4], some factors also concerned how the industrial scale, industrial

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structure, technological progress, environmental protection and investment, energy structure, population size, openness to trade / FDI and geographical factors affected pollutant emission[5-8].In some other studies also referred to measuring industry sectors' pollutant emission and strength [9], assessing environment-friendly state level of 30 manufacturing industries [10], discussing industry concentration, labor factor, capital and technological factors on the pollution intensity of manufacturing industry [11], and the relationship between pollutant emission and industrial characteristics, environmental regulation[12].Although there were less researches above, they put a major step forward than those simply verifying the existence of EKC curve because the former referred to the impact of industrial characteristics of national various sectors on pollutant emission.

1.2. Quantitative identification of industrial clusters

Multivariate cluster analysis has not been much applied in identifying regional industrial clusters [13-14]. Principal component analysis has been much applied in many studies [15-17]. However, principal or secondary component depends on the contribution rate of industry groups to regional industry development, which is not relevant to close linkage between industries in one group. Czamansk method has a logical program, focused on the linkage between different industries in a cluster [18-20]. However, it does not deal with the clusters composed of similar key departments well. Besides the statistical analysis above, network analysis method has been applied. With plenty of applications of complex network, it will bring a new sense of quantitative identification of industry cluster [21].

2. Data

In this paper we use the input-output data of Shandong province in 2002, which contains the basic flows between 42 industries. There were a total of 39 departments after removing three waste product and other waste departments. The other data of the paper was industrial added value in Shandong Statistical Yearbook from 1990 to 2008, corresponding to their pollutant emission amount as well as the whole province's industrial waste and solid waste emission amount.

3. Method

3.1. Quantitative extraction of industrial associations

First we treated the basic flow data with horizontal and vertical maximum standardized, and then calculated Pearson correlation coefficients, selected effective industry associations with a one-tailed test value above the threshold level of 0.05. Without regard to the relationship between industries, we did union operation to the effective correlation matrixes in both input and output directions, then binarized the matrix after union operation, finally there was a non-directional symmetric binary matrix about industry association. We applied the method of complex network clustering algorithm based on simulated annealing algorithm.

3.2. Direction in the industrial chain

First, compare the value flow between one pair industries and determine the leading direction by the larger flow. Then we chose the average of all the edges' flow as the threshold value, below which the edge would be removed. There would be a new community in which the link between industries was relatively close. Finally industry nodes were linked according to the leading direction between industry pairs.

3.3. Ridge regression analysis

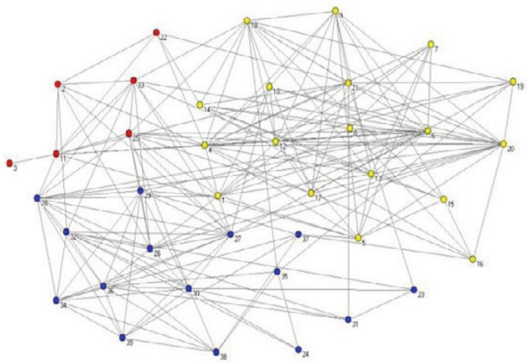
When the variable has the obvious collinearity phenomenon, the multi-dimensional linear regression method based on the least squares method estimated the parameter often presents a big deviation. For the more accurate estimate of return parameters, it is needed to eliminate the collinearity when building models to satisfy the request that independent variable mutually are independent. Ridge regression method was introduced in this paper, with the discussion about the relations between industrial node and pollutant emission. k value's determination is the key matter which was solved by the two methods of the ridge trace graph and residual sum of squares of equation.

4. Result

4.1. Quantitative extraction of industrial chain

The modular index of society classification was 0.32, which ranged from 0.3 to 0.7. 39 industries were divided to three societies (see fig1). Society I contained 18 departments, eighty percent of which belonged to manufacturing category (see fig 2). Society II contained 15 departments. Society III contained the fewest departments, in which there was a larger heterogeneous than society I and II.

The extraction result of the industry chain was showed in figure 3. In this chain there were 7 industries. Stream value between industries in the transmission process decreased step by step from the top industry to the downstream industries, but the value between general/special equipment manufacturing industry and transportation equipment manufacturing industry increased sharply.(see fig.3).



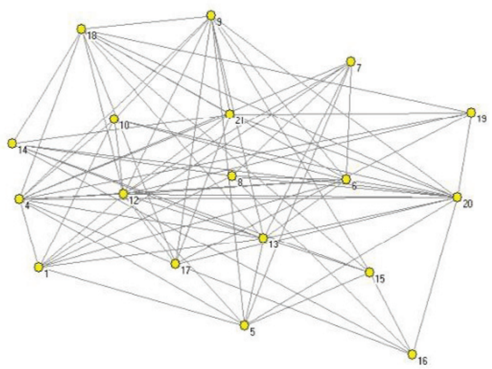


Fig.1. The classification result of industry associations based on 39 departments Fig.2. A manufacturing-based industry association

1. Agriculture-forestry-animal husbandry-fishery 2. Coal mining and washing industry 3. Petroleum& natural gas mining industry 4. Metal ore mining industry 5. Non-metal ore mining industry 6. Food manufacturing and tobacco processing industry 7. Textile industry 8. Clothing & leather & down product industry 9. Wood processing and furniture manufacturing 10. Papermaking & printing & cultural and educational articles manufacturing 11. Petroleum &coking & nuclear fuel industry12. Chemical industry 13. Non-mental mineral product industry 14. Metal smelting & calendering and processing industry 15. Steel wire products industry 16. General/special equipment manufacturing 17. Transportation equipment manufacturing 18. Electric machinery equipment manufacturing 19. Communication and computer equipment manufacturing 20. Instrument and cultural &office working articles manufacturing21. Electric power and thermal energy production supply industry 22. Gas production and supply industry 23. Water production and supply industry 24. Construction industry 25. Transportation and storage industry 26. Postal industry 27. Information- computer and software service industry 28. Wholesale and retail sale trades 29. Lodging and catering industry 30. Financial and insurance industry 31. Real estate industry 32. Lease and commercial service industry 33. Tourism industry 34. Scientific research work 35. Synthetic technique service 36. Educational undertakings 37. Health and social security &benefits industry 38.Cultural & physical & entertainment industry 39. Public management and social organization

$$\mathbf{1} \xrightarrow{10215072} 6 \xrightarrow{4827708} \mathbf{12} \xrightarrow{1922278} \mathbf{7} \xrightarrow{725126} \mathbf{8} \xrightarrow{592707} \mathbf{16} \xrightarrow{1292667} \mathbf{17}$$

Fig.3. The identified industrial chain in a quantitative method based on community I

Bold number means industry department referred in Fig.1, Number above the arrow means the value flow from one department to the other.

4.2. The scale of the industry chain in economy and pollutant

In this paper, we had selected six manufacturing industries except agriculture-forestry-animal husbandry-fishery industry in the chain to discuss each industry's contribution on pollutant emission.

The proportion of six manufacturing' industrial added value in the province as a whole had increased year by year from 2000 to 2007. In 2007 it reached 50.96% and their value accounted for 25.93% of the whole province's GDP. In the year of 2000, the proportion of six manufacturing industries in the province's above-scale industries' wastewater as a whole was 33.85%, solid waste 15.12%. The latter had decreased to 13.10% by 2007, but the former increase to 46.86%.

It should be pointed out that before 2000 there was not the data about pollutant emission corresponding to industry sectors. Therefore the amounts of two kinds of pollutant were computed by the formula 1 below from 1989 to 2000.

$$s_{jt} = a_{jt}\left(\frac{1}{7}\sum_{j=1}^{2} p_{jk}\right) \qquad (1)$$

t is the year from 1989 to 2000, j denotes the type of pollutant, s_{jt} denotes the amount of one pollutant each year from 1989 to 2000, a_{jt} denotes the amount of one pollutant from the whole province's industries each year from 1989 to 2000, k denotes the year from 2001 to 2007, p_{jk} denotes the proportion of six manufacturing industries' pollutant amount in the whole province's industries' as a whole each year from 2001 to 2007.

4.3. Contribution rate of industries in the chain to pollutant emission

The existence of the collinearity of independent variables should be diagnosed before modeling by the tolerance factor and variance inflation factor. The variance inflation factor was measured by the formula 2 below.

$$VIF_{jj} = \frac{1}{1-R_j^2}, \quad j=1,2,3...p \qquad (2)$$

VIF_{jj} is the variance inflation factor, R_j denotes multiple correlation coefficient.

Generally considering there was serious collinearity of independent variables when VIFjj was greater than or equal to 10. The calculation of the collinearity was showed in table 1.

Tab.1 The diagnosis of the collinearity of six industrial value-added variables

Independent variable	Tolerance	Variance inflation factor
food manufacturing and tobacco processing industry	0.003	304.985
chemical industry	0.001	1487.060
textile industry	0.002	619.076
clothing & leather & down product industry	0.001	709.723

general/special equipment manufacturing industry	0.001	696.812
transportation equipment manufacturing industry	0.005	207.136

After ridge regression model statements were written to Spss software, there were ridge traces of six independent variables. The ridge trace was a curve of ridge regression estimate value when each variable Xi changed with K value, which ranged from 0 to 1. It was the key step to determine K value. The criteria was to ensure the stabilization of ridge trace of each variable. In this paper both the ridge trace graph method and residual sum of squares of equation were applied for selecting K value. The principle in the latter was to make the ratio of the ridge regression estimation's residual sum of squares to least squares estimation' residual sum of squares not increase too much. Both the two residual sums of squares above and their ratio were calculated corresponding to K value ranging from 0 to1(see fig.4, fig.5).

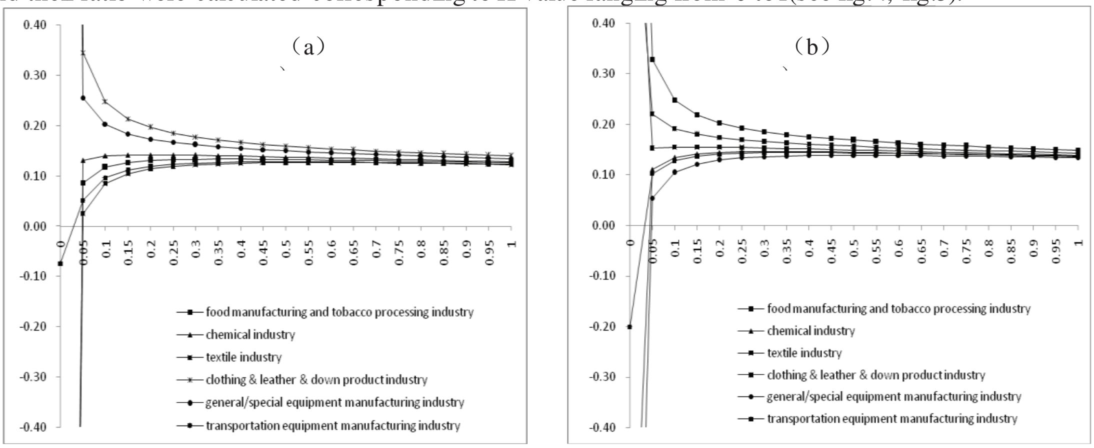


Fig.4 The ridge traces of six variables in Model I (a), Model II (b)

In figures 4 and 5 we can clearly see when K value equals to 0.3 the ridge regression coefficients of variables in model I and II tend to keep stable, while the variation in the ratio of one couple of residual sum of squares appears to be stable. In the figure 7 the variation in the ratio in the two models has become moderate after a turning point. When K value reached 0.3 the ridge regression estimation was appropriate. The ridge regression equations in two models were listed as follows.

Model I： $Y_{\mathrm{I}} = 0.1332x_1 + 0.1409x_2 + 0.1223x_3 + 0.1773x_4 + 0.1620x_5 + 0.1255x_6$ （3）

Model II： $Y_{\mathrm{II}} = 0.1854x_1 + 0.1460x_2 + 0.1531x_3 + 0.1659x_4 + 0.1359x_5 + 0.1436x_6$ （4）

$\mathrm{Y_I}$ and $\mathrm{Y_{II}}$ respectively denote industrial waste water and solid waste amount in the chain. Six variables denote in sequence industrial added value of food manufacturing and tobacco processing industry, chemical industry, textile industry, clothing & leather & down product industry, general / special equipment manufacturing industry and transportation equipment manufacturing industry. Both independent variables and dependent variables are normalized. The coefficients in two models are standardized partial regression coefficients.

F test value in model I was 8.850, which was statistically significant at the level of 0.001 indicating that the model was credible (see tab.2). R square denoted the degree how independent variables explained dependent variables. Adjusted R square was 0.724 indicating that variables could explain 72.4 percent of industrial wastewater amount in the chain. In the chart 6 the coefficients of variables were standardized partial regression coefficients in ridge regression equation, whose absolute value can be used to express the contribution rate of each variable to variation of dependent variable. Hence, the contribution rate of each industry in the chain to the variation in industrial wastewater amount could be measured by the absolute value of standardized partial regression coefficient. Certainly the influence of each industrial added value on industrial wastewater amount would be explained through partial regression coefficient. However, the two kinds of coefficients differed in quantity size.

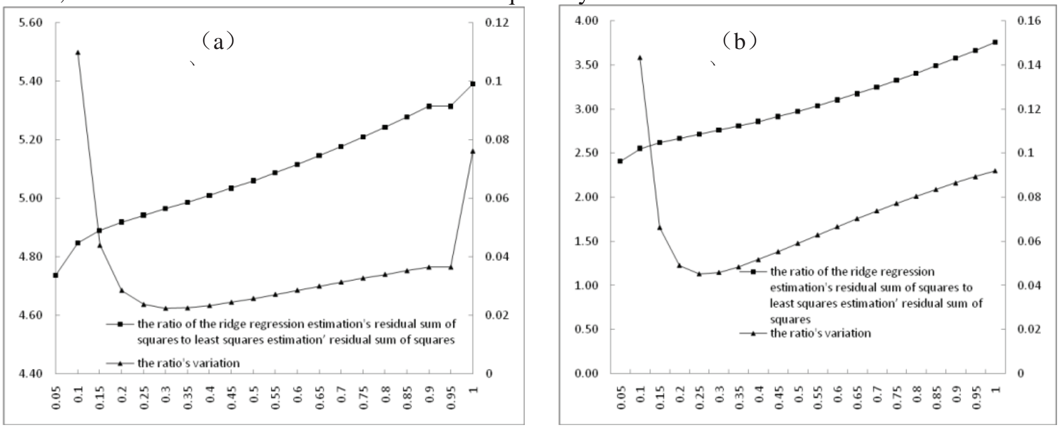


Fig.5 The ratio of the ridge regression estimation's residual sum of squares to least squares estimation' residual sum of squares and its variation in Model I (a), Model II (b)

Tab.2 Statistical parameters in the two ridge regression models when k equals to 0.3

Explanatory variables	Model I Standard partial regression coefficient	Model II Standard partial regression coefficient
food manufacturing and tobacco processing industry	0.1332	0.1854
chemical industry	0.1409	0.1460
textile industry	0.1223	0.1531
clothing & leather & down product industry	0.1773	0.1659
general/special equipment manufacturing industry	0.1620	0.1359
Transportation equipment manufacturing industry	0.1255	0.1436
R Square	0.816	0.950
Adjusted R Square	0.724	0.925
F value	8.850	38.217
Sig.	0.001	0.000

The contribution rate of industrial added value of six industries in the chain to industrial wastewater emission amount was 15.3%, 16.5%, 13.9%, 21.5%, 19.4% and 14.3% respectively(considering 72.4 percent of explanation of six variables in model I for the wastewater amount variation as 100 percent). The contribution from clothing & leather & down product industry was the most, followed by general/special equipment manufacturing industry and chemical industry. This is due to the common effect from both the transfer from upstream industries' pollutant and the its own pollutant emission. However, each industry in the chain differed in both the two effect above-mentioned.

F test value in model I was 38.217, which was statistically significant at the level of 0.000 indicating that the model was credible (see tab.2). Adjusted R square was 0.925 indicating that variables could explain 92.5 percent of the variation in dependent variable, which was higher than the explanation in model I. The contribution rate of industrial added value of six industries in the chain to solid waste emission amount was 20.0%, 15.8%, 16.6%, 17.9%, 14.7%, 15.5% respectively(considering 92.5 percent of explanation of six variables in model II for the solid waste amount variation as 100 percent). The contribution from food manufacturing and tobacco processing industry was the most in six industries, followed by clothing & leather & down product industry and textile industry.

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